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THE VARIATION OF LATITUDE AT OTTAWA 1952–53*

BY D. L. G. MILLER AND R. W. TANNER

THE Ottawa photographic zenith tube (figure 1), of 10-inch aperture and 167-inch focal length, was mounted in the Dominion Observatory in the fall of 1951, and has now been in operation for two full years. A description of the instrument and its auxiliary equipment, together with an outline of the method of calculating the results is soon to be published.

The PZT, as it is called for brevity, has an objective mounted half the focal length of the lens above a basin of mercury, so that the image of a star overhead is reflected onto a small photographic plate immediately below the objective. The plate moves back and forth along a way rigidly attached to the objective in order to obtain a point image. Each star is photographed four times, twice before and twice after it crosses the meridian. Lens and plate are turned a half circle about the vertical between successive exposures of the same star. This procedure eliminates most of the errors afflicting ordinary telescopes. The four resulting images form a rectangle or rhombus; a score of these can be seen in figure 2.

The tilt of the rhombus indicates whether the star was photographed too early or too late, and since the times at which the exposures are made are controlled by one of the Observatory's crystal clocks, measurement of the east-west distances on the plate leads to determination of the clock variation. This is the main function of the PZT nowadays, but for years before it was adapted to this purpose, it was used at Washington to record the variation of latitude. To determine this, half the north-south height of the rhombus is measured, giving the star's distance north or south of the zenith.

*Contribution from the Dominion Observatory, vol. 2, no. 18.

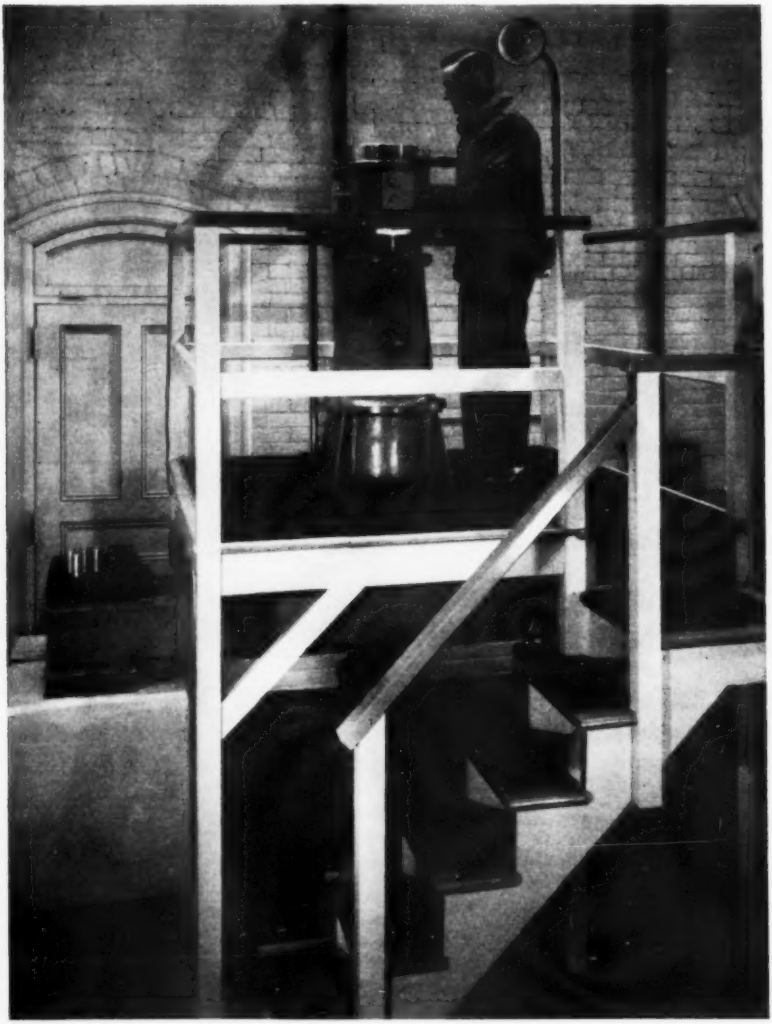

FIG. 1—Ottawa photographic zenith tube.

Now if the star and the telescope are both always at the same angular distance from the equator, the star must always transit at the same distance from the zenith. This is not found to be the case however; even

after making allowance for the effect of precession, nutation, aberration and proper motion on the star's position, its zenith distance varies up and down by several tenths of a second of arc from its mean value. As one second of arc corresponds to about 100 feet on the earth's surface, this would imply that the observer's latitude has changed by dozens of feet.

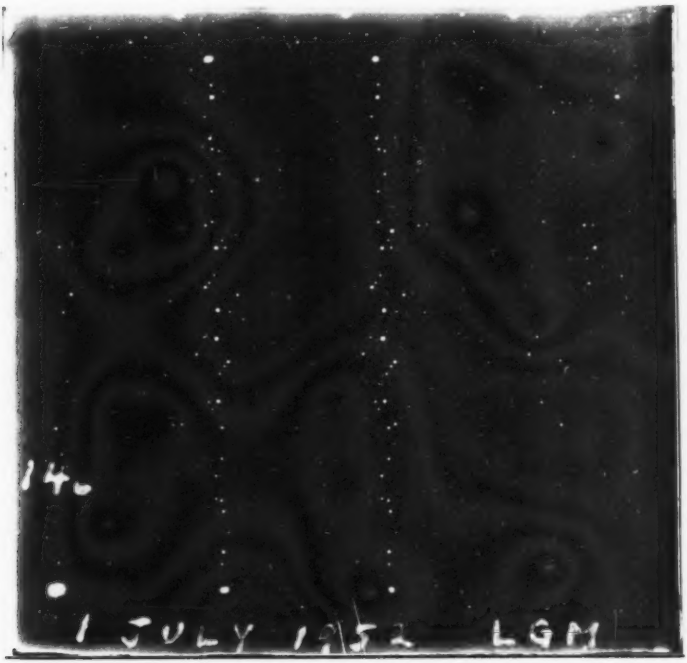

FIG. 2—Star plate taken with Ottawa photographic zenith tube.

The explanation lies in the fact that the axis of rotation of the earth is not a fixed line in the earth; its ends wander in small irregular spirals about the mean poles. Figure 3 shows the path of the north end of the axis of rotation of the earth about the mean pole from 1949 to 1951. When, for example, the instantaneous pole of rotation is at A, the latitude of any observer in 0° longitude is 0″.37 larger than its mean value, or 0″.37 smaller for observers in longitude 180°; the latitudes of observers in longitudes 90° west or east are equal to their mean values. Later, when the pole has moved to B, observers in longitudes 0° and 180°

will experience their mean latitude, while the latitudes of observers in longitudes 90° west or east will be 0″.23 smaller or larger respectively, than their average. It will be seen how a record of the variation of latitude at stations in different longitudes enables the path of the pole to be traced.

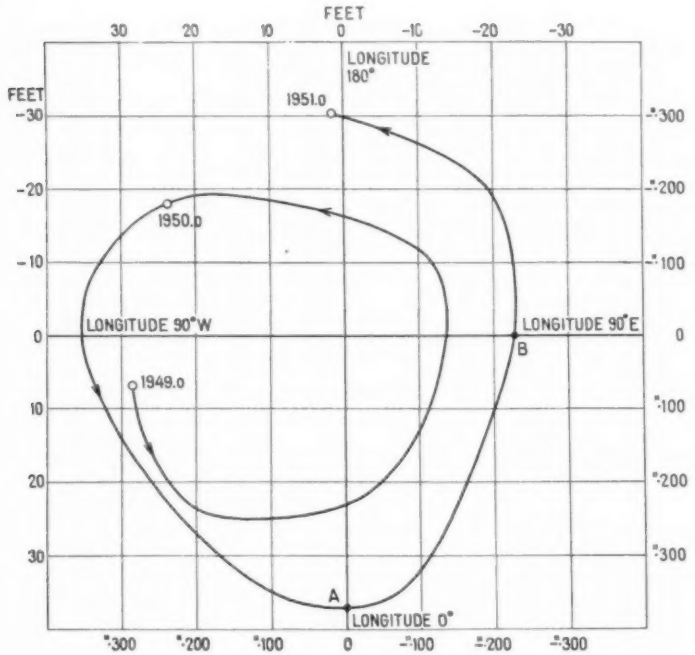

FIG. 3—Polar motion, 1949–51 (I.L.S.).

This polar motion, though small, must be allowed for in the most precise astronomical determinations of time and position. The general motion has been analysed into an annual part due to meteorological and other seasonal effects, and a part of 14-month period, the Chandler term. But there are other unpredictable variations as well, so that continuous observations of the variation of latitude at many stations are necessary.

A list of 146 stars, of mean photographic magnitude 8.0, within 15′ of the zenith at transit, is regularly observed at Ottawa. They are fairly evenly distributed into 12 two-hour groups in right ascension, and on each clear night as many stars as possible of two successive groups are

photographed. Each month a later group replaces an earlier group when the latter's transit time begins to approach evening twilight.

When a star crosses the meridian its distance z from the zenith is equal to the difference between its declination δ, and the observer's latitude ϕ. That is, $\phi = \delta \pm z$, plus if the star passes south of the zenith, minus if north. In the Ottawa instrument one second of arc in the sky corresponds to one-fiftieth of a millimetre on the photographic plate, so before measuring the zenith distances the images are enlarged seven times in a projection device. The star's declination for the transit having been calculated, the latitude follows from the formula above. This is repeated for all the programme stars on the plate, and an average is taken. Then all these nightly values are averaged again about twice a month. These fortnightly averages are shown as small circles in figure 4.

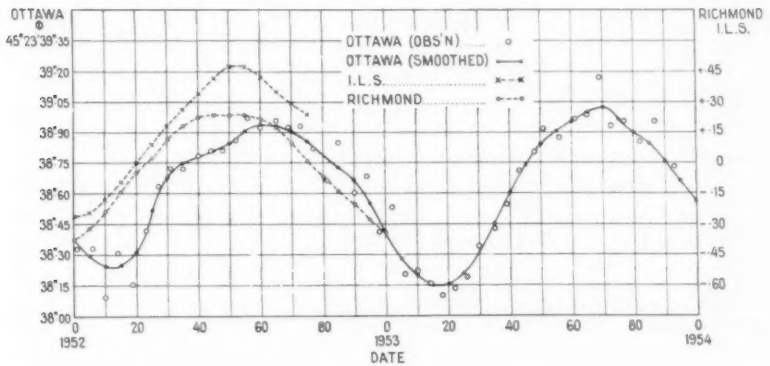

FIG. 4—Variation of latitude as observed at Ottawa and Richmond and as issued by the International Latitude Service.

Now it is found from the interagreement of the ϕ's of a single night that the probable error of a single ϕ is about 0".20, and since the error of a mean varies inversely as the square of the number of observations, the mean ϕ for a full plate of 24 stars should be less than 0".05 in error if only the accidental errors of measurement and of the values of δ used were in question. However the average ϕ's of the various nights of the fortnightly period differ by a couple of tenths of a second, as may be seen in Table I, giving the nightly means for the latter part of March 1954.

These differences are probably due to varying inclinations of the layers of equal density in the atmosphere above the PZT, or to small horizontal temperature gradients in the air inside the instrument. A north-south

TABLE I

OBSERVED MEAN LATITUDE—OTTAWA

Date	Latitude
1954	45° 23′
March 18	38″.20
21	.31
22	.44
23	.25
24	.35
27	.33
30	.23
31	.27

tilt in the air layers of one tenth of a degree, or a temperature difference across the tube of as little as one twentieth of a degree Centigrade would account for a 0″.10 apparent change in the latitude. These fluctuations are encouraged by the PZT's being housed at present in a substantial stone building of great heat capacity. To average out these effects the fortnightly means are smoothed twice by averaging together each set of three adjacent points with weights 1–2–1 to give the continuous curve shown in figure 4. Table II gives the Ottawa provisional latitudes at intervals of 0.05 year for 1952 and 1953.

For purposes of comparison the variations of ϕ measured by the Richmond (Florida) PZT, together with the variation furnished by the International Latitude Service, are shown for part of this period. The American station, being nearly in Ottawa's longitude should show much the same results. In plotting the two comparison curves, the mean latitude of the PZT is taken as 45° 23′ 38″.75 as indicated by meridian circle observations.

The small fluctuations in the Ottawa curve for 1952 are due in part to erroneous values of the declinations employed. The original values were provided through the courtesy of the Naval Observatory, Washington, which collected the best available recent observations of these stars into a provisional catalogue on the FK3 system with epoch 1950. The epochs of observation were from 20 to 40 years earlier, and the proper motions of many of the fainter stars being rather uncertain, some of these provisional positions are in error by over a second of arc. It is seen that if several stars in a group have δ's too low, the ϕ's will come out too low also.

When the complete list has been observed in the course of a year, the

TABLE II

SMOOTHED LATITUDE OBSERVATIONS, OTTAWA, 1952–53

Date	Latitude	Date	Latitude
1952.00	45° 23′ 38″.37	1953.00	45° 23′ 38″.40
05	.29	05	.28
10	.24	10	.20
15	.25	15	.15
20	.31	20	.15
25	.52	25	.21
30	.68	30	.34
35	.74	35	.45
40	.78	40	.60
45	.81	45	.74
50	.85	50	.84
55	.91	55	.91
60	.94	60	.95
65	.93	65	39.00
70	.91	70	.02
75	.86	75	38.96
80	.78	80	.90
85	.73	85	.85
90	.67	90	.76
95	.55	95	.66
		1954.00	.56

individual δ's can be corrected by regarding the latitude as known. Most of the larger errors in the catalogue were removed at the end of 1952, and the 1953 variation is much smoother in consequence. The positions for 1954 are further improved by combining the previous corrections to the declinations with the results of a programme of meridian circle observations of these stars. When definitive positions for all the stars are attained these provisional results may be amended.

Dominion Observatory,
Ottawa, May 1954.

FERUT, CANADA'S ELECTRONIC COMPUTING MACHINE

By Jean K. McDonald*

In a brief review of the history of computing machinery, how far back shall we go—to the era of finger counting, for this was primitive man's method of computing? Perhaps not so far back, but we must recall two of the earliest contributions, the introduction of the system of decimal notation, or counting based on groups of ten; and the invention of the abacus, a computing device that in the hands of a skilled operator is speedy even by modern standards.

Although many important advances in computing methods, such as the introduction of logarithms, were made during the intervening centuries, it was not until 1642 that the history of mechanical computing machines began, with Pascal's invention of the numeral-wheel machine. This device made use of wheels which rotated any one of one to nine steps to register the decimal digits one to nine, with a zero-carrying mechanism for each ten units passed through by the wheel. There followed in 1673 the invention by Leibnitz of the stepped-cylinder machine, which was the pattern for the first calculating machines to be manufactured industrially, by Thomas of Colmar, France, around 1820. The basic principles of these early inventions, modified to provide greater versatility, accessibility and speed, are to be found in such well-known modern desk-model electrically operated calculating machines as the Monroe, Friden and Marchant.

One drawback of such a machine, however, is that it requires the human operator at every step in a problem. What is desirable is a machine that, once started, will proceed automatically, step by step, through a sequence of arithmetical operations, without human intervention. Such an automatic, sequence-control machine was conceived around 1835 by a Cambridge mathematician, Charles Babbage, in his plans for what he called an analytical machine, but his ideas were to lie dormant for over a century, principally because technological developments were not sufficiently advanced to provide the necessary parts—the hardware of the machine. His plans provided for controlling a sequence of computing processes by means of a set of punched cards, an invention that was inspired by the working of the Jacquard weaving looms, and that finds a counterpart in the modern punched-card equipment of the International Business Machines Corporation.

*Dominion Astrophysical Observatory, Victoria, recently having undertaken a numerical investigation of model stellar atmospheres, at the Computation Centre, University of Toronto.

By far the best descriptions we have of Babbage's analytical machine and of its capabilities were written by a contemporary, Ada Augusta, the Countess of Lovelace, a daughter of the poet Lord Byron. Lady Lovelace was a remarkable woman mathematician, remarkable in that so few women in that day had any formal training in mathematics, and in that her writings indicate she possessed the necessary mathematical and mechanical insight to appreciate the manner in which a mathematical problem, when properly analysed, could be dealt with by the machine, a performance not to be demonstrated for some one hundred years.

Babbage is perhaps better known for his invention of the difference engine, a machine that not only could check existing arithmetical tables, by computing their second- and higher-order differences, but could build up the tables by working back from the difference column. One such engine that he built and put into operation worked to six decimal places and used second-order differences. With it tables were calculated in 1863, to be used for many years for the computation of life insurance premiums. It is of special interest to us to record that in 1823 the Royal Astronomical Society awarded Charles Babbage its first Gold Medal for his invention of the difference engine.

It was not until the year 1944 that the difficulties that lay in the way of the actual construction of Babbage's analytical machine had been overcome, for in that year the first large-scale automatic, sequence-control calculating machine, developed by Professor H. Aiken and the International Business Machines Corporation, was put into operation at Harvard University. While the new machine differed from the earlier proposed model in the component parts, yet it and the many similar computing machines in use today embody to a startling degree the mathematical design of Babbage's analytical machine.

Through the many articles of a popular nature in newspapers and magazines, most people to-day are aware that modern electronic computing machines have tremendous capacities for storage of information (their so-called memories), that they perform arithmetical operations with fantastic speeds, that they cost a great deal of money, and that they are tagged with names suggested by the initials of the words describing them.

The machine at Toronto, the only general-purpose, electronic, digital computing machine in Canada, is called Ferut, the first three letters coming from the name of the manufacturer, Ferranti, Ltd., of England, and the last two letters from the University of Toronto.

Ferut was purchased jointly by the National Research Council of Canada and the Defence Research Board, at a figure in the neighbour-

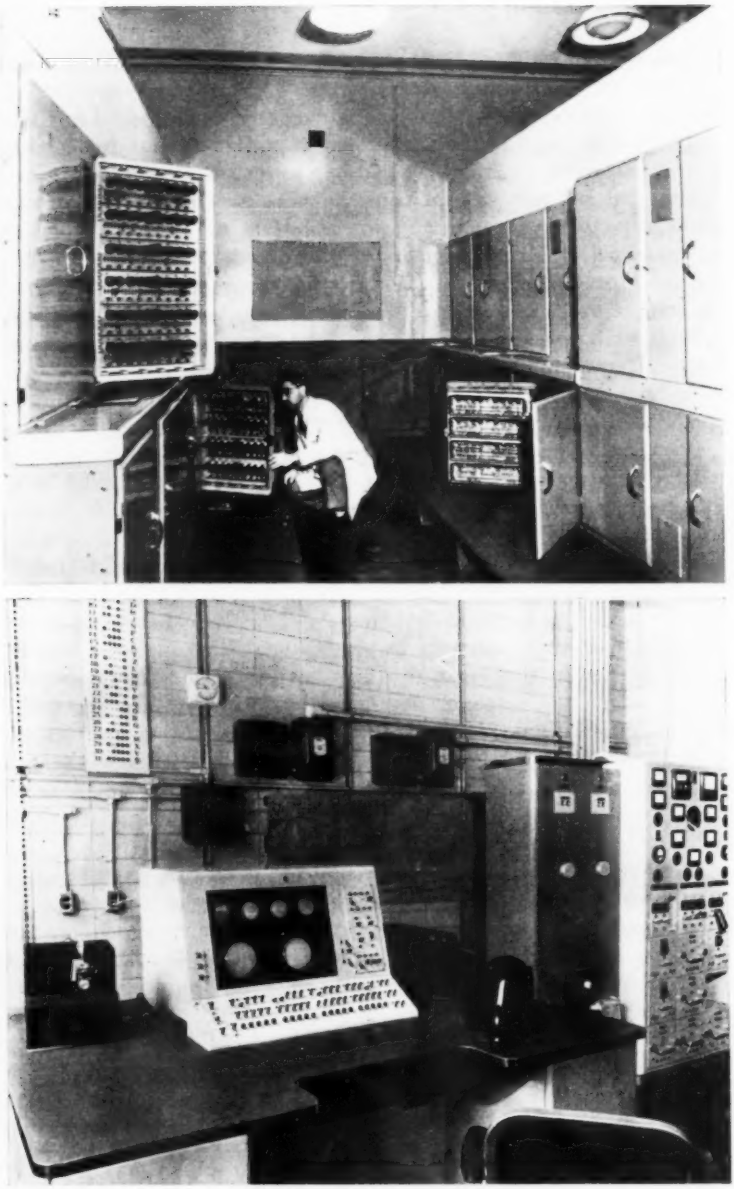

FIG. 1—Two views of Ferut, the electronic computing machine at the University of Toronto.

hood of $250,000, and was shipped directly from the place of manufacture, Manchester, England, to Toronto, in the spring of 1951. It is installed in the McLennan Laboratory of the University of Toronto, where it is operated under the supervision of the Computation Centre of the Department of Physics.

The policy of the Centre is to make Ferut available to governmental and privately owned scientific organizations and to such industrial groups in Canada as may beneficially use its services. To this end, the Centre is prepared to instruct representatives of such organizations in the use of the machine (as in my case) and to allow the use of the machine on an hourly rental basis. Alternatively, the Centre undertakes to handle a submitted problem, making a charge for the use of the machine and for the time of the mathematician working on the problem. The Centre has a staff of eight to ten mathematicians and physicists, and in addition, Atomic Energy of Canada Limited, the National Research Council of Canada, and the Defence Research Board each maintains a staff at the Centre to deal with its specific problems.

The accompanying photographs will help to describe Ferut. At first glance the portion shown in the upper of the two photographs looks much like two rows of gleaming metal kitchen cabinets, each about 16 feet long, 8 feet high and 4 feet wide. The open cabinet door reveals that within is a mass of electrical equipment. The lower photograph shows the console, or control desk, at which the operator of the machine sits and where, before him, are some seventy levers and buttons, and six screens. These screens, similar to, but smaller than ordinary television screens, have individual displays, and when the machine is in operation the displays show a constantly changing pattern of bright and less-bright green spots. The pattern of the spots tells the operator what instruction the machine is at that instant obeying, and what numbers or instructions are located in any of the numerous storage units of the machine.

To understand the significance of the spots, we must know that Ferut, in common with many similar machines, works with binary numbers, that is, numbers on the scale of two rather than ten, as in our ordinary decimal notation. Whereas in the decimal system numbers are represented by combinations of the ten decimal digits (0 to 9), in the binary notation numbers are represented by combinations of the two binary digits (0 and 1). When we look at the screen, a bright spot represents the digit 1, a spot of less brightness the digit 0. The convenience of binary representation is that it permits the corresponding use of elements with two and only two mutually exclusive conditions; for example, an electrical relay may be either on or off, a signal may

indicate the presence or absence of an electrical pulse, at a specified position on a paper tape a hole may or may not be punched, and on the viewing screen a spot may be bright or less-bright.

In the ordinary decimal representation of numbers, successive digits stand for successive powers of ten; in the binary representation, successive digits stand for successive powers of two. As an example, consider the number 46 and its binary representation.

Decimal	*Binary*
46	101110
$4\times10^1 + 6\times10^0$	$1\times2^5 + 0\times2^4 + 1\times2^3 + 1\times2^2 + 1\times2^1 + 0\times2^0$

For convenience in writing down binary numbers, a symbol called a character is used to denote each group of five binary digits. There are 32 possible combinations of 0 and 1 in groups of 5, hence we need 32 symbols to represent them. We use the 26 letters of the alphabet, and 6 additional characters, \$, ½ , / , @ , : , " . In the lower photograph, the binary representation of some numbers is shown on the board attached to the back wall. (The alert reader may protest that this is a mirror image of the correct representation; as a matter of fact, Ferut is designed to use binary numbers with the most significant digit at the right and not at the left as in the usual decimal representation.) After the number 31, a second group of five binary digits is built up, and hence all numbers larger than 31 are represented by two or more characters.

The modern electronic computing machine may be considered to have five basic units: an input mechanism for receiving the data of the problem (the numbers and the instructions); a storage unit where the data are retained; an arithmetical unit where the operations of addition, subtraction, multiplication, are performed; an output mechanism to supply the operator with the results of the problem; and finally, a control unit to form the link between any two of the other units.

On the front right side of the desk in the photograph can be seen the input mechanism of Ferut, a photoelectric tape reader. On the narrow white band of paper tape, constantly passing over the tape reader during input, has been punched a pattern of holes to represent the data. These data may be in the form of either instructions or numbers, usually a combination of both, set up in groups of 0's and 1's, with the 0 represented by the absence of a hole, and the 1 by the presence of a hole in one of the five hole positions across the width of the tape. Thus, on each line of the tape can be represented five binary digits, or one character.

Ferut has two different forms of output mechanism, both are shown

in the lower photograph toward the back of the table and on either side of the upright portion of the console. At the left is the device that presents the results in the form of punched tape, at the right the typewriter that presents the results in printed form, in either decimal or binary notation, on ordinary sheets of paper. The particular form of output, determined by the operator beforehand, is indicated by him in the instructions on the input tape.

Storage facilities in Ferut are of two types: electronic, consisting of eight cathode ray tubes, each capable of storing 1280 binary digits, or 32 numbers of 40-binary digit size. (A 40-binary digit number is approximately equivalent to a 12-decimal digit number, since 2^{40} is approximately equal to 10^{12}). These numbers are stored as electrical charges on the inner surface of the front of the cathode ray tube. The second type of storage is magnetic. Here the information is stored by means of magnetized areas of nickel on the cylindrical surface of a rotating drum, there being provision for 256 peripheral areas or tracks. The capacity of each track is equal to that of two electronic stores. Thus there can be stored in the magnetic memory of the machine, to be used at any time, 655,360 binary digits (equivalent to 16,384 12-decimal digit numbers). Transfer of one track of data may be made from the electronic to the magnetic stores in about one-twentieth of a second, and the two lower viewing screens shown in the photograph may display at any time the contents of any two of the electronic stores.

The arithmetical unit is similar in design to that of a desk-model calculating machine, consisting of a multiplicand register and an accumulator register. The control unit selects information from successive positions of a store, interprets it as an operating instruction or a number, and causes the arithmetical unit to perform the designated operation. The addition of two 12-decimal digit numbers can be done in about one one-thousandth of a second, multiplication in about two one-thousandths of a second. An example of the speed of operation of Ferut may be taken from a portion of one problem. Values were required that were functions of two variables. Using Ferut, 400 values were computed in three minutes, whereas an estimate of the time required using an ordinary electrically-operated desk machine is about one hundred hours—a ratio of about two thousand to one. The power that is demonstrated in a problem of this kind is in the speed of handling single mathematical operations performed many times. Another even more powerful feature of electronic computing machines is that their use makes it possible to deal with mathematical problems of such extent that they cannot be handled by ordinary methods. An example of this was the problem undertaken by the Computation Centre and the

Ontario Hydro-Electric Power Commission, the computation of the water levels in the proposed St. Lawrence Seaway. This has been probably the major single undertaking in the two years of operation of Ferut and required many hundreds of hours of machine time.

Throughout the history of computing machinery, the requirements of astronomy have helped to direct the research into new machines, and the methods of astronomical computations have in turn been quickly adapted to the new machines. It is of interest to note that the first scientific application of the punched-card system was that of L. J. Comrie in the British Nautical Almanac Office in 1928, in a verification of E. W. Brown's theory of the motions of the moon. Information from Brown's tables was punched on half a million cards, and used to compute the position of the moon for the years 1935 to 2000, at 12-hour intervals. From these results the tables in the Nautical Almanac that give the position of the moon every hour were prepared by a machine whose principles are similar to those of Babbage's difference engine. It is reported that Brown had begun the checking of his theory by ordinary methods of computing, and it is easy to believe the report that it was with "ecstasies of rapture" that he watched the punch-card machine adding at the rate of 20 to 30 numbers per second the data that he had so laboriously compiled by hand.

By the year 1932 all of the calculations done in the British Nautical Almanac Office had been completely mechanized. The Nautical Almanac Office is now a branch of the Royal Observatory at Herstmonceux, and the equipment of that office includes punched-card machines, tabulators, sorters, collators, reproducers, all typical commercial machines. As an example of their usefulness, the production of the Nautical Almanac and other astronomical tables calls for the annual computation and printing of about 5000 pages of over 7,000,000 figures. In 1950 automatic methods were introduced into the proof-reading as well as the preparation of such tables, resulting not only in greater speed but also in a standard of accuracy never before attained.

In the United States, the American Astronomical Society, the Astronomy Department of Columbia University and the International Business Machines Corporation have set up a joint enterprise at Columbia University, making available to astronomers punched-card methods of computation and a vast file catalogue of astronomical data. Studies undertaken with this equipment deal with such topics as planetary and lunar motions, stellar positional catalogues, photometry, and stellar statistics.

In Canada, the Dominion Observatory has recently had computed, on

Ferut, a problem of reducing observed stellar positions to positions for a mean epoch, the results to be used in connection with their well-known accurate time service. In a problem of this kind, it is estimated that Ferut can do the calculations at least one thousand times faster than they could be done by ordinary desk machines.

Within the past few years a number of research problems in astrophysics have been undertaken with the aid of electronic digital computing machines. As an example, in 1952 numerical results were obtained which gave confirmation to the theory of Bondi, Hoyle and Lyttleton for the accretion of interstellar material by a star. The exensive computational work leading to these results was done by K. N. Dodd on the Manchester University Electronic Computer (of the same manufacture as, and almost identical with Ferut). At the present time, perhaps half a dozen astrophysical investigations aided by electronic computing machines are under way in the United States and Canada, dealing with such topics as stellar interiors, stellar evolution and stellar atmospheres. It is in connection with the latter problem that use is being made of Ferut, and a brief report of the investigation may be of interest here.

It is in the outer region of a star, the region known as its atmosphere, that the radiation or light we receive from the star, and photograph in the form of a spectrum, takes on its characteristic appearance. This appearance, the variation in intensity of the background continuous portion as we go from the blue end of the spectrum to the red, and the intensity and shape of the absorption lines, will depend upon the physical conditions (temperature, pressure, opacity) of the atmosphere of the star. A table of the numerical values of these parameters as they vary with depth in the atmosphere is called a model of the atmosphere, and it is possible to calculate the characteristic spectrum such an atmosphere would emit. The model stellar atmosphere may be taken to represent the atmosphere of an actual star when the spectrum calculated for the model matches the spectrum observed for the star, and in this way the numerical values describing the physical conditions of the actual star can be determined. The calculation of the model stellar atmosphere and of the spectrum it would emit must be performed in such a way as to assure that certain conditions of mechanical and radiative equilibrium are satisfied. The complexity of the problem arises because of the interlocking or interdependency of the various parameters, in particular because the continuous opacity is not constant with wave-length; that is, more radiation will be absorbed from one portion of the spectrum than from another, and further, this variation with wave-length is in turn variable with depth in the atmosphere.

While the saving in computing time is a strong argument for the use of an electronic computing machine on a problem like this, from the scientific point of view it may not be the most important feature. Using an electronic computing machine, it is hoped that it will be possible to construct a model atmosphere taking into account the interdependency of the various parameters to an extent not possible by desk-machine methods.

To give some idea of the storage requirements that this problem imposes, there must be computed by the machine and stored on its magnetic tracks from 200 to 400 values of each of 21 functions of two variables—a total of over 200,000 binary digits. About half of the numbers so represented provide the data for over 200 equations in 39 unknowns, which are then reduced to 39 normal equations. The difficulty of solving even six equations in as many unknowns by ordinary desk-machine methods will illustrate the rather spectacular power of a machine like Ferut in solving sets of equations in 39 unknowns—a problem that does not tax its ability at all, since it has already handled similar problems of five times the size.

Lest a wrong interpretation be placed on these latter remarks it should be emphasized that the most powerful and versatile modern computing machine is itself incapable of initiating and solving a mathematical problem. It can do only those things that its operator had in mind when he gave it its instructions. As a matter of fact, more, rather than less human thinking is required to solve a problem on such a machine than on an ordinary desk-model machine, because every possible situation that may arise in the course of the problem must be thought out beforehand and the machine instructed what to do when that situation arrives. For this reason, I should like to protest the use of the terms "mechanical brain", "thinking machine", and the like, as applied to computing machines. Lady Lovelace made a statement in describing Babbage's analytical machine, which bears repeating, for it is equally true for modern computing machines. She wrote: "The analytical machine has no pretensions whatever to originate anything. It can do whatever one knows how to order it to perform."

In conclusion, I would like to acknowledge that much of the historical information included here came from the book *Faster Than Thought*, recently published by Pitman and Sons, and written by B. V. Bowden and his colleagues in England, a book that gives a humorous, readable and clear account not only of the history, but also of the theory and design of computing machines.

A PERIOD-LUMINOSITY RELATION FOR THE β CEPHEI VARIABLES*

By R. M. Petrie

ABSTRACT

Spectroscopic absolute magnitudes are determined for seven β Cephei stars from measures of the total absorption at Hγ. These absolute magnitudes give a period-luminosity relation $M = +0.4 - 18.1\ P$ and establish the reality of a correlation with reasonable certainty.

The β Cephei stars have recently become of increasing interest to astronomers. Interest in this peculiar class of variable stars has been stimulated largely by a series of well-planned studies carried out by Professor O. Struve and his colleagues at Berkeley and at the Lick Observatory.[1] β Cephei variables or, alternatively, β Canis Majoris variables are exclusively early spectral type ranging from B1 to B3, and exhibit continuous cyclic variations in light, colour, spectral type, and radial velocity. The spectral lines usually vary in appearance changing their depths and widths during the cycle. The variation of radial velocity is substantial; the light and colour variations are small and can be measured adequately only with the help of photoelectric photometers. The varying characteristics are periodic, or nearly periodic, in their repetition. The cycle is always short, ranging among the known examples from about three hours to about six hours.

The light, and velocity, variations are correlated in a manner rather similar to that observed for the classical Cepheids. There is, however, a difference in the phase correlations of about one-quarter of the period in that the maximum of light in the β Cephei stars occurs at the time of smallest stars (on the pulsation hypothesis) whereas in the Cepheids it happens at the time of maximum velocity of contraction.

The similarities in the β Cephei, and Cepheid, variables have led to searches for a period-luminosity relation among the former stars since such a relation has long been known to exist among the latter. The relation between period and luminosity for the Cepheids has proved to be of great value in estimating the scale of the galaxy and the distances to extra-galactic objects; the establishment of a relation among

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the β Cephei stars would likewise be of interest and would be an additional clue to our understanding of stellar variation. Already it has been pointed out by McNamara[2] that a relation is indicated and recently Blaauw and Savedoff[3] have published a relation between period and luminosity, for the β Cephei stars of the form

$$M = -10 - 9 \log P,$$

where M is the absolute visual magnitude and P is the period expressed in days.

It is not easy to be certain of the form of the relation or even that its existence has yet been demonstrated. The known examples are few in number and it is extraordinarily difficult to determine a distance, and hence an absolute magnitude, for any B-type star because they are generally so remote. The absolute magnitudes for three out of the six stars used by Blaauw and Savedoff were determined from the observed proper motions, a method not altogether satisfactory when applied to individual stars. It is not surprising that the above authors urge the need for a better determination of the relation, pointing out that the probable error in the slope of their correlation is about thirty per cent. McNamara did not give any numerical correlation, contenting himself with a plot of period *versus* luminosity for six stars, employing some of the data used by Blaauw and Savedoff.

The above mentioned difficulties led the writer to make a determination of the relation employing the recently-established system of spectroscopic absolute magnitudes.[4] This method makes use of the total absorption of Hγ as a measure of absolute magnitude and is believed to yield fairly reliable values. It may be remarked that any correction to the Victoria system, which may subsequently be required, should not seriously affect the *slope* of a period-luminosity relation for β Cephei stars since their range in luminosity is moderate, and rather substantial second-order corrections would be required to change the slope. We may hope then to establish whether there exists a period-luminosity relation for β Cephei variables even if the absolute value of the constant term should require future correction.

The observational data are the periods and spectroscopic absolute magnitudes for seven β Cephei stars as shown in the table. The measured intensities of Hγ are published values for β Canis Majoris[5] and γ Pegasi.[6] The other determinations were made at this Observatory by standard spectrophotometric techniques. The values of Hγ are listed together with the number of spectrograms used, and the deduced absolute visual magnitudes are given along with the periods and spectral types.

The accompanying figure shows plotted as filled circles our observational data from which it is evident that there is good reason to accept the existence of a period-luminosity relation. The data are not considered extensive enough to warrant introducing curvature; a linear relation was found by a least-squares solution giving all points equal weight.

H.D.	Star	Period	Type	Hγ	No. of Plates	M_v
		days		A.		
886	γ Pegs	0.1513	B 2.5	4.2		−2.5
16582	δ Ceti	0.1610	B 2	4.7	4	−2.1
44743	β CMaj	0.2500	B 1	2.9		−3.85
199140	BW Vulp	0.2010	B 1	3.3	31	−3.4
205021	β Ceph	0.1902	B 1	3.4	3	−3.25
214993	12 Lacr	0.1930	B 2	3.7	5	−2.9
216916	16 Lacr	0.1693	B 2	4.1	4	−2.7

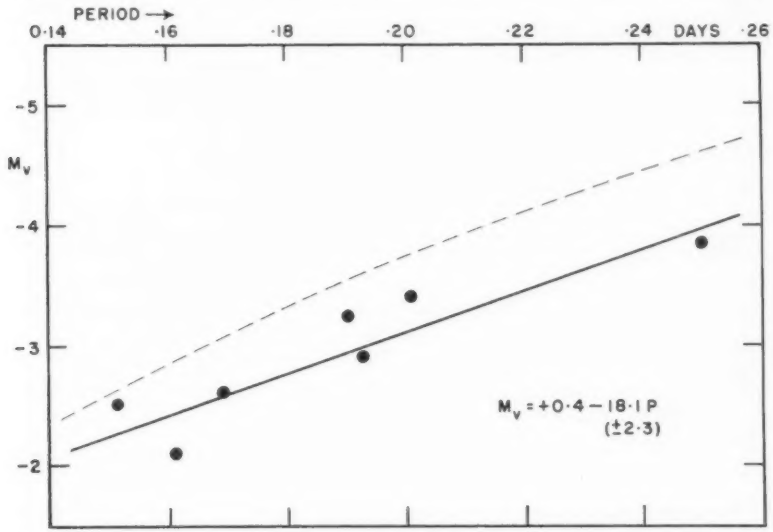


FIG. 1—A Period-luminosity Relation for the β Cephei Variables. The filled circles represent the observational data for seven β Cephei stars. The relation derived from these data is shown by the solid line. The law deduced by Blaauw and Savedoff is shown by the broken line.

The relation was found to be

$$M = +0.4 - 18.1\ P,$$

and the probable error in the coefficient of P is 2.3. The probable error in the slope is therefore one-eighth of its value which allows one to presume with some assurance that a period-luminosity relation among the β Cephei stars does, in fact, exist.

The derived relation is drawn on the figure as a solid line and the law deduced by Blaauw and Savedoff is shown by the dotted curve. It is obvious that our observations would be quite well fitted by a logarithmic curve and the above authors give some arguments to indicate that the relation will be of that form. As far as the observational material goes, however, that is a refinement which may well await the accumulation of more data.

It will be noticed that there is a systematic difference of about 0.4 mag. between the two relations, the Victoria values being the fainter. It may be caused, at least in part, by an error in the absolute values of the spectroscopic parallaxes and future work will no doubt rule on this matter. The important point however is that the existence of a relation appears to be established with reasonable certainty.

References

1. See, for example, *An. Ap.*, Paris, vol. 15, p. 157, 1952; *Ap. J.*, vol. 116, p. 81, p. 99, and p. 106, 1952; *Ap. J.*, vol. 118, p. 39, 1953.
2. *P.A.S.P.*, vol. 65, p. 155 and p. 286, 1953.
3. *B.A.N.*, vol. 12, p. 69, 1953.
4. R. M. Petrie, *P. Dom. Ap. O.*, vol. 9, p. 251, 1953.
5. E. G. Williams, *Ap. J.*, vol. 83, p. 279, 1936; A. B. Underhill, *Ap. J.*, vol. 104, p. 388, 1946.
6. E. G. Williams, *Ap. J.*, vol. 83, p. 279, 1936; A. B. Underhill, *Ap. J.*, vol. 107, p. 349, 1948.

Dominion Astrophysical Observatory,
Victoria, B.C.,
June 1954.

NOTES FROM OBSERVATORIES

David Dunlap Observatory

Solar Eclipse Expedition to Mattice

Although the expedition of the David Dunlap Observatory to Mattice, Ontario, to observe the total solar eclipse of June 30, 1954, was fruitless on account of a heavy overcast, it is no doubt worth recording the observations which it was planned to make there.

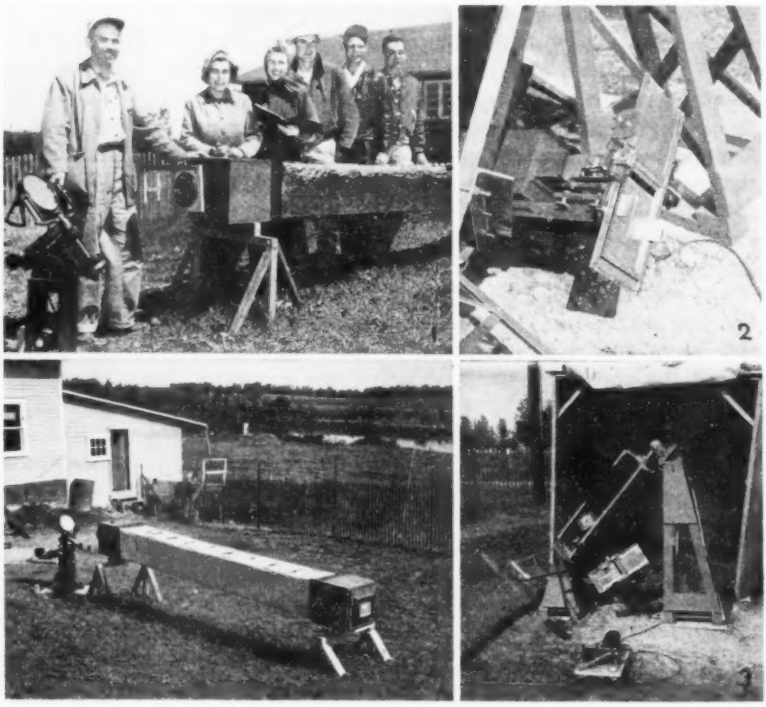
The plans for the expedition were made by Dr. John F. Heard and Dr. J. B. Oke with Mr. G. F. Longworth, the Observatory mechanician, constructing the necessary new equipment and adapting the old for this eclipse. These three also formed the advance party which went to Mattice on June 12 to set up and test the equipment at the site. Joining the party on June 26 to assist in the operation were Miss Ruth J. Northcott of the Observatory staff, Dr. Allan Sandage of Mount Wilson and Palomar Observatories and Dr. Shirley Jones of the Buffalo Museum of Science. The group is shown in figure 1.

The project was three-fold in purpose: to study the flash spectrum in the near infra-red region of the spectrum, to compare the polarization of the corona in the blue region with that in the near infra-red, and to record the appearance of inner and outer corona on fairly large-scale photographs.

The site chosen for the observations was the schoolyard at the village of Mattice, latitude 49° 36′ 51″ N., longitude 83° 15′ 48″ W., as determined for the party by the Geodetic Survey of Canada. This position was about three-quarters of a mile north of the predicted centre line of totality.

The spectrograph for the flash spectrum was built in the Observatory workshop by Mr. Longworth. It was of the slitless form, and it utilized a plane grating ruled by Wood which has a strong blaze in the first order in the neighbourhood of 8000 A. A camera lens of 25-inch focal length produced a spectrum which, on a curved film, could be focussed well from 6200 A. to 8800A., the region which is well covered by Eastman 1N emulsion. The dispersion was about 22A./mm. which would be a considerable improvement over the dispersion of 80 A./mm. used by Mitchell in his investigation of the flash spectrum in this spectral region at the 1937 eclipse. In an effort to catch the required moment of the

flash spectrum and at the same time to record the spectrum of the photosphere at the sun's limb for calibration purposes, a jumping plate mechanism, operated by a synchronous motor, was constructed. This permitted alternate exposures of 0.2 sec. and 2.7 sec. with 0.2 sec. "dark time" for the transit of the film holder between each exposure. The mechanism is shown in figure 2. Two film holders were provided, each holding a film 5 inches wide and 8 inches long. These film holders provided for nine pairs of exposures (long and short) of the spectrum of the crescent at both second and third contacts. Each cycle of exposures thus would occupy 30 seconds. It was intended to start each cycle approximately 15 seconds before the predicted moment of second



FIGS. 1–4: 1. *Left to right*: J. F. Heard, F. Shirley Jones, Ruth J. Northcott, Allan Sandage, G. F. Longworth, J. B. Oke (Courtesy *Toronto Daily Star*). 2. Jumping plate mechanism. 3. Polar axis carrying the polarigraph and spectrograph. 4. Long camera and coelostat.

and third contact; in this way it was hoped that the sets of spectra would include not only several usable flash spectra but at least one short-exposure continuous spectrum which would serve for calibration purposes. To record the precise times of the exposures, contacts on the shutter operated the relay of a chronograph pen which was also actuated by time signals from station CHU, Ottawa. During all tests this equipment operated well, though provision was made to put on signals from a chronometer manually in case of failure of the CHU reception.

The polarigraph which was to have been used to study the polarization of the corona consisted essentially of a four-lens camera of 40-inch focal length built by Dr. R. K. Young for the 1922 Australian eclipse expedition for a similar purpose. Three of the lenses were fitted with HN22 polaroid filters which provided almost 100 per cent. polarization from 4000 A. to 9000A.; these filters were arranged with their axes at 120° from one another which would permit study of polarization in all directions from the sun's centre. The fourth lens carried a neutral, non-polarizing filter with approximately the same transmission. This quadruple camera was fitted with a single shutter of the barn door type and the intention was to obtain both light and strong sets of exposures with both Eastman IIaO plates (for the blue) and 1N plates (for the infrared). The front of the quadruple camera is seen in figure 3.

Both the spectrograph and the polarigraph were mounted on a yoke-type polar axis which was counterweighted to be heavy towards the west and which was driven by the unwinding of a steel cable which passed from a four-foot sector clamped to the axis to a two-inch drum which was rotated at the proper rate by a synchronous motor working through a set of reducing gears. Figure 3 illustrates the polar axis.

Large-scale photography of the corona was to have been accomplished by the Cooke four-component astrographic lens of 11-foot focal length which was used by C. A. Chant and R. K. Young for the Einstein effect in Australia. A wooden frame mounted horizontally on trestles served as a camera for this lens and the sunlight was fed to it by means of a coelostat. Eastman 103aE plates would have been used with a yellow plexiglass filter placed just before the focal plane. Exposure times from one sec. to 40 sec. were planned. Figure 4 shows the long camera and coelostat.

Preparations were completed on the evening before the eclipse. All types of emulsions were calibrated for photometry with a spot sensitometer, and the 1N films to be used for the flash spectrum were sensitized by cold water bathing. Drills had been worked out and practised repeatedly. However, four hours before eclipse a cold front

moved into the district and the sky was completely overcast so that none of our observations was possible. A flying boat chartered by the *Toronto Daily Star* was standing by on nearby Shallow Lake, and it had been planned that under certain cloud conditions Dr. Donald A. MacRae of the Observatory staff and one or more members of the ground party would go aloft to observe and photograph the eclipsed sun. Dr. MacRae was to have participated in a project of the Canadian Broadcasting Corporation to send a description of the phenomenon in advance to Sweden. However, the ceiling was so low at Shallow Lake that the aircraft could not take off. Thus all our party had to content ourselves with the sudden and spectacular darkening of the sky and landscape. Many residents of Mattice and visitors had come to the schoolyard, and after totality was over they were admitted to the compound for a closer look at the equipment before the process of dismantling was begun.

It is a pleasant duty to express our appreciation to all who assisted us in many ways. The expedition was made possible by a grant from the National Research Council and a research grant from the University of Toronto. For transportation of equipment and people to and from Mattice, General Motors Products put at our disposal for three weeks a Chevrolet "Suburban"; this was a very acceptable gift, simplifying our problem enormously. Eddie Black's Camera Shop in Toronto and Graflex of Canada loaned us a Graflex camera and telephoto lens with which we had hoped to obtain pictures of the corona from the air. As already mentioned, the *Toronto Daily Star* arranged places for us in their aircraft. The Coca Cola Company loaned us a cooler for transporting our films and plates, most of which had to be kept refrigerated the whole time. At Mattice, Rev. Joseph Proulx, the parish priest, was most kind to us, obtaining the requisite permission to use the site, allowing us to use part of his home for a laboratory, lending us many needed articles and providing us power from his home circuit. Likewise the sisters who teach in the school were very kind to allow us to use a part of the school for a darkroom and to lend us things we needed. We had help too from the Department of Highways, the Ontario Hydro Commission and the Ontario Provincial Police. All of these people and organizations as well as many tradespeople and others in Mattice were equally helpful to several groups of American scientists who located in and about Mattice.

Although our efforts were fruitless, the experience of this eclipse expedition was altogether pleasurable, and we hope we may find it of value at a future eclipse.

J. F. H.

METEOR NEWS

By Peter M. Millman, *Dominion Observatory, Ottawa*

A Provisional List of the Major Meteor Showers

In compiling a list of the chief meteor showers of the year it is very difficult to know where to draw the line. There is no sharp division between the major and minor showers and in the accompanying list I have included twenty showers, the choice of this number being purely arbitrary and of no special significance.

The list is an attempt to compile useful information for the meteor observer. It makes no pretence at being complete, nor should the figures given in the various columns be considered as accurate final values. As far as possible a reasonable average has been taken from various recent publications dealing with these showers, more weight being given to photographic and radio recording methods than to the purely visual observations. Brackets indicate a doubtful or very tentative value.

In general the showers in this list are the best annual showers but the Aurigids were included chiefly because they are in a very lean portion of the year; and the Giacobinids and the Bielids, though generally absent during the average year, have produced remarkable displays in the past. In compiling the data, sources too numerous to list in detail have been consulted. These included the papers on photographic meteors from the Harvard Observatory, the radio observations made at the University of Manchester, and the visual results collected by C. P. Olivier and C. Hoffmeister. Use has also been made of the Canadian meteor observations, many of which have been published in the Journal. The individual columns of the table are explained below:

Column 1 The most generally accepted name for the shower.

Column 2 The longitude of the sun at maximum. This must be used to compute the exact time of maximum for any given year.

Column 3 This date may vary by one depending on the location of the observer and the relation of the year in question to leap year.

Column 4 Many of these radiant positions are averages of a fairly diffuse radiant area.

Column 5 Note that the daily motion in right ascension is given in minutes of right ascension, not arc. To convert to arc multiply by the cosine of the declination of the radiant.

Column 6 It is very difficult to list good relative hourly rates. These given here are only general averages and vary considerably from year to year. They are for

PROVISIONAL LIST OF THE MAJOR METEOR SHOWERS

Shower	At Shower Maximum				Daily Motion of Radiant		Equivalent Total Hourly Number of Meteors for Single Observer at Shower Maximum	Normal Duration	Photographic Radiant Spread	Observed Geocentric Velocity	Associated Comet
	$\lambda\odot$	Mean Evening Date	Radiant (1950) α	δ	α	δ		(days)		(km./sec.)	
Quadrantids	282.7	Jan. 3	231°	+50°			35	1		41	
Aurigids	321	Feb. 9	75	+42			12	(5)			
Lyrids	31.5	Apr. 21	273	+34			12	2		48	
η Aquarids	44.3	May 4	336	0	+ 53′	+22′	12	10		(66)	Halley
o Cetids	59	May 20	30	− 3			15 (daytime)	10		37	
ζ Perseids	77.2	June 8	62	+24	+ 66	+27	30 (daytime)	15		29	
Arietids	77.2	June 8	44	+23	+ 42	+33	45 (daytime)	20		38	
Scorpio-Sagittarius	83	June 14	260	−26	+ 52		12	80			
Draconids	97	June 28	220	+58			12 (10 in 1916)	(5)			Pons-Winnecke
β Taurids	98	June 29	86	+18	+ 48	+24	35 (daytime)	10		31	
δ Aquarids	127	July 30	340	−15	+ 52	+12	20	15	0.°7	41	
Perseids	139.2	Aug. 11	46	+57	+ 81	+ 8	50	20	0.6	61	1862 III
Giacobinids	196.2	Oct. 9	262	+54	+126	− 6	(20,000 in 1933; 1,000 in 1946☾)	1	0.1	23	Giacobini-Zinner
Orionids	207.0	Oct. 20	95	+15	+ 74	+ 8	20	10		66	Halley
Taurids	218.0	Oct. 31	54	+17	+ 35	+ 8	12	30	0.9	30	Encke
Northern Arietids	230	Nov. 12	50	+22			12	(5)			
Bielids (I)	232.5	Nov. 14	24	+44			(5,000 to 10,000 in 1872, 1885)	1		(16)	Biela
Leonids	234.0	Nov. 16	152	+22	+ 42	−25	20(>10,000 in 1833; 1,000 in 1867☾)	5	0.2	72	1866 I
Geminids	261.1	Dec. 13	113	+32	+ 63	− 4	40	5	0.2	35	
Ursids	270.5	Dec. 22	207	+80			15	(1)			

an observer plotting and include the sporadic meteors which contribute an average hourly rate of approximately 7. The daytime rates are determined by radio methods and are given on an equivalent basis to the visual rates.

Column 7 This is not the extreme possible duration of the shower but a practical figure indicating a period over which a reasonable number of the shower meteors may be observed. The relative sharpness of the shower maximum may be judged from the duration.

Column 8 The radiant spread is the probable error of the deviations of the individual meteor trails from a point radiant.

Column 9 The best average of the actual velocities observed, both photographic and radio, is given.

Column 10 These comets move in very similar orbits to those of the meteors and are probably physically connected with them.

REVIEW OF PUBLICATIONS

The Nature of Science and Other Lectures by Edwin Hubble. Pages viii + 83; 8½ ×5 ½ in. The Huntington Library, San Marino, California, 1954. Price $2.00.

The contents of this book, hitherto unpublished, have been selected from the author's nonscientific writings. Edwin Hubble was one of the greatest astronomers of all time, and it is with more than passing interest that we delve into his more general writings.

In "The Nature of Science", Hubble clearly distinguishes the realm of science from the world of pure values. He tells how observations are described by laws, laws explained by theories, and theories tested by new observations, etc. There seems to be no finality in the world of science. It is one of probability. In the world of values, finality is possible. Man may know the ultimate truth beyond a shadow of a doubt, although he cannot communicate the certainty to one who does not share his ecstasy.

The second lecture, "Science and Technology", emphasizes the interdependence of science and technology. The position of the scientist as an understander of the world and not as a benefitter of mankind is difficult for the public to accept.

"Experiment and Experience" is a commencement address given at the California Institute of Technology. It is a plea for the young scientist to learn the values of humanism.

"O'er the Ramparts We Watch" was delivered on Armistice Day 1941, a few weeks before Pearl Harbour. Again it is a plea, this time for U.S. participation in World War II—"Better a Bolshevik who kills Germans than a Democracy that kills time".

In "The Scientist at War", Hubble tells some of his experiences in, and views on, ballistics research. The article is well written, giving a good idea of the scientist's job in time of war.

"The War That Must Not Happen", written in 1946, tells how technology has converted war into world suicide. Hubble suggests that any coming war will not be stopped by international treaty agreements or the outlawing of major weapons. We must not expect any combatant in a life and death struggle to fight with one hand tied behind him. A world authority, once established by agreements in the form of a constitution, would be above and independent of the individual nations, if armed with a sufficiently powerful police force. We must take immediate action.

Hubble's book is informative, stimulating, and above all, timely. One should feel duty-bound to read it, even though one may not be in accord with all of Hubble's ideas.

W. R. H.

NOTES AND QUERIES

Percival Lowell and Mars

As we look at Mars this year, we cannot help but think of Percival Lowell, that very fine and conservative astronomer who first made the world aware of the possible existence of Martians. Advances in knowledge since his time have made certain of his opinions, particularly earlier ones, untenable. However, change in opinions is the penalty of growing knowledge, and Lowell certainly helped to push knowledge and thought forward while he lived.

Of interest is a quotation from a letter of Lowell's, written in the early part of this century:

"Just back from my excursion to Kingman—The Judge says it was a great success. And I suppose a judge should know. Certainly I made some friends; even among the Socialist miners, which was my aim.—— One of the miners afterward came up and expressed his interest in the astronomical part of the lecture, adding with gusto that he liked my politics too. I had shown how the solidarity of the Martian canal system points to an efficient government in which the best men are at the front and then I went on to show its applicability to us".

W. R. H.

Hurricanes

The most destructive of all storms is the hurricane. This is a huge atmospheric whirl, turning counterclockwise in the northern hemisphere, clockwise in the southern, with spiralling inflowing winds which are high enough to be destructive, and have been measured to be close to 190 miles an hour. There is a low-pressure area at the centre (the eye of the storm) where the pressure may be as much as 10 per cent. lower than at the edge. There is a large cloud area, from which rain pours in torrents. The whole phenomenon is from 300 to 600 miles in diameter and moves along at a moderate speed.

The devastation from a hurricane comes not only from the great winds but from the huge waves built up on the sea. Around the fringe of the hurricane tornadoes may be generated which show concentrated fury and destructiveness.

The kinetic energy spent by a mature hurricane is incredible, amount-

ing to the equivalent of several thousand atomic bombs a second, according to R. H. Simpson in the June issue of *Scientific American*. The question of how this tremendous power is generated is of interest to meteorologists.

Since 1944 detailed information about hurricanes has been collected by using three methods: radiosonde balloons, radar and reconnaissance flights in aircraft. The radiosonde enables the procurement of a continuous record of temperature, pressure and humidity. The radar screen has revealed the spiral pattern of the rain clouds; these are often visible from an airplane, but are rarely detectable in good perspective from the ground. The spiral squall lines remain one of the greatest puzzles in hurricane structure.

The energy in a hurricane is obtained from the latent heat released by water vapour condensing in the air. The surface winds spiralling around the centre, force moist air violently upward at a rate which may exceed a million tons a second. As this air is cooled, the moisture is condensed out and forms rain. The condensation releases great amounts of latent heat, raising the temperature in this region. Temperature differences from the centre to the edge of from 15° to 30° have been measured. The spiralling air moves outward by centrifugal force and prevents the storm from decaying.

It appears that the moist air, the main source of the hurricane's energy, comes from near the surface of the sea, and that very little is obtained at levels above 2000 feet from the surface. It was found from observations from aircraft that most of the air in the middle and upper layers of the central region had descended from great heights. There must be outflow at intermediate levels, for otherwise the pressure of the air coming in from both top and bottom would build up and destroy the storm.

The circulation of winds at very high levels is still not understood. A theory has been developed connecting the speed and direction of a hurricane's advance with the wind velocity at a certain high level, called the "steering level". As more observations in this region are obtained, it will be possible to make more accurate predictions of the motion of hurricanes, and thus reduce loss of life and property.

R. J. N.

A New Sky Atlas

It has recently been announced that the publication of the unique National Geographic Society-Palomar Observatory Sky Atlas will begin next year. It will include 14- by 14-inch photographs taken with the

48-inch Schmidt telescope and will cover about three-quarters of the entire sky. Each area exposed is about as large as the bowl of the Big Dipper and each photograph slightly overlaps the exposures of adjoining areas. Each area is photographed twice, on blue-sensitive and red-sensitive plates, in immediate succession. Some features are present only on the plates sensitive to one of these colours, or are more clearly evident on one than on the other. The total of 1,758 prints should provide enough material for a century of study. The atlas will be made available to observatories and research institutions at a price estimated at about $2000. This covers only the cost of production and handling of the prints. The plates and other supplies used in the Survey and the salaries of the personnel required are provided by the National Geographic Society, while the observing time necessary to take the negatives for the Survey is provided by the Palomar Observatory.

B. R. G.

Two New Supernovae

As a result of a systematic search for supernovae made with the 18-inch Schmidt telescope of the Palomar Observatory, two such objects were discovered by Dr. Paul Wild within one month. The first was discovered on May 4 in N.G.C. 5668 in the constellation Virgo, and was magnitude 14 at the time of discovery. The second was found on May 30 at magnitude 12.5, in N.G.C. 4214 in Canes Venatici.

A spectrum of N.G.C. 5668, obtained by Dr. Milton Humason with the 200-inch telescope, indicates that the object is moving away at a speed of a thousand miles a second. Using the velocity–distance relation, the distance of this supernova is about twenty million light-years. It is estimated that it is a few hundred million times brighter than the sun. In fact both the new supernovae belong to the brightest type, called type I.

During the last twenty years several dozen supernovae have been found in different galaxies. It is estimated that in any one galaxy a supernova will appear about once every 500 years. There are thousands of galaxies, but since the flare-up lasts only a short time only a few supernovae are actually photographed.

R. J. N.

Polar Cap of Venus

Among the few details observed on the surface of Venus there is a remarkable hump near the south pole. This so-called polar cap was recently observed by Russian amateur astronomers.

Because of the regular appearance from cycle to cycle some people think that the polar cap is connected with the pole of Venus. Assuming the surface of the planet is covered with clouds and assuming that the observed features in the atmosphere reflect the structure of the surface, then, the polar cap is caused by a higher luminosity of the atmosphere, which is connected with a higher reflectivity of the surface at that place.

Theoretical considerations show that the polar cap should be visible only if the plane through the planet, perpendicular to the line of sight, goes also through the polar cap. Observations have shown that this condition is fulfilled near the heliocentric longitudes of Venus of 130 and 310 degrees.

If the assumption is correct that the polar cap represents the south pole of Venus, it was found from observations that the axis of rotation of Venus is inclined to the orbit at an angle of 51 degrees with a mean error of 3 degrees.

From the point of view of future observations it would be desirable (1) to confirm the visibility of the cap near heliocentric longitudes of 130 and 310 degrees, at the terminator, (2) to follow statistically the appearance of white spots as the projection of the polar cap on the disk between longitudes 130 and 310 degrees, (3) to find whether there is anything like a north polar cap.

(Condensed from the *Bulletin of the Soviet Astronomical and Geodetical Society*, No. 12, p. 3, 1953).

G. A. B.

VARIABLE STAR NOTES
American Association of Variable Star Observers

By MARGARET W. MAYALL, *Recorder*

052404 S Orionis. One of the great advantages of having continuous visual observations of the long-period variables was pointedly brought out at the recent meeting of the American Astronomical Society at Ann Arbor, Michigan. Dr. Freeman D. Miller reported on a study of stellar spectra in the far infra-red, with wavelengths of 9000 to 11000 A. One of the stars on his programme was the variable star S Orionis. In order to secure some photographs of its infra-red spectra near maximum light, when it should be about 8th magnitude, Dr. Miller computed the time of maximum from the elements given in the "General Catalogue of Variable Stars" by Kukarkin and Parenago. S Orionis has much variation in its epoch, and a photograph of it near the predicted maximum light showed a bare trace of the variable.

Dr. Miller asked for A.A.V.S.O. observations, and we were able to give him a curve of current observations which showed that the variable was almost completely out of phase. At the time of his photograph, it was near minimum and between 12th and 13th magnitudes.

Figure 1 shows the observed light curve of 052404 S Orionis from the beginning of A.A.V.S.O. observations in 1911 to the present day, and covers the epochs 36 to 73, as numbered by Leon Campbell in the *Harvard Annals*. Times of maxima and minima are indicated with tick marks above and below the curves. These times were determined by superimposing a mean light curve on the observed curve, and reading off the dates of the best fits. The mean light curve used was the most recent one determined by Leon Campbell, and is to be published in the near future in the *Campbell Memorial Volume*.

Table I lists in successive columns: 1. mean maximum magnitude; 2. date of maximum; 3. difference (maximum minus maximum); 4. epoch number; 5. mean minimum magnitude; 6. date of minimum; and 7. difference (minimum minus minimum).

The best value for the period of S Orionis for the years 1911 to 1954 is 415 days, but a glance at the columns of differences will show that period means very little with this star. The differences range from 380 to 446 days. The mean maximum magnitude of S Orionis is 8.5 and minimum is 12.8.

A photographic patrol of long-period variables such as S Orionis would be too costly of both time and materials to be practical. Visual observations, made by amateur astronomers who are anxious to help the scientists, make the perfect solution. The case of S Orionis is just one more example of the usefulness of their work.

Krüger 60 B. This red dwarf flare star at R.A. $22^h24^m.4$ Decl. 57° 12′ north has been

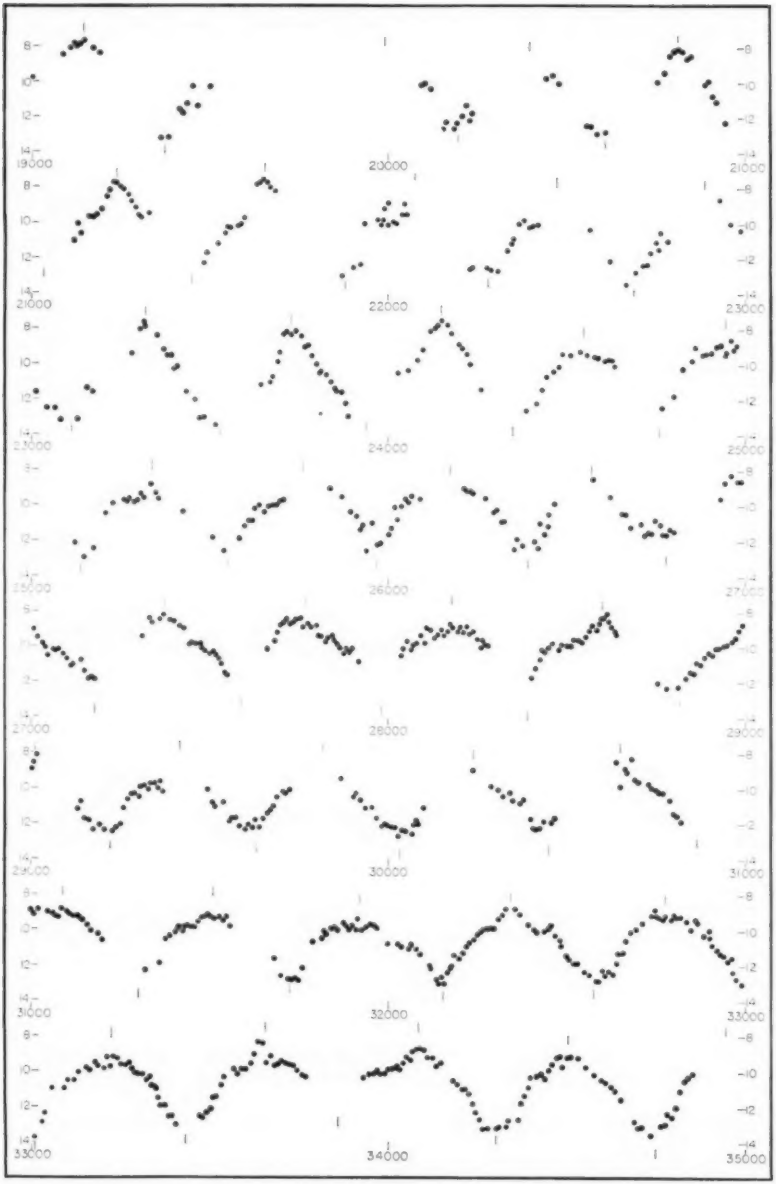


FIG. 1–S Orionis 052404. 10-day Mean Light Curve, 1911–1954.

observed by Gunnar Darsenius in Sweden for a total of 4½ hours during the last year. No flare was observed, but the negative observations are of great value statistically. A list of flare stars which merit such observations was given in these notes in January 1953 (vol. 47, no. 1, p. 24).

TABLE I

S ORIONIS 052404

MAXIMA				MINIMA		
Mag.	J.D.	Diff.	No.	Mag.	J.D.	Diff.
7.8	19145	437	36	13.2	19362	..
..	19582	408	37	..	..	..
..	19990	405	38	12.7	20198	412
..	20395	422	39	12.9	20610	424
8.1	20817	421	40	..	21034	416
7.7	21238	416	41	..	21450	430
7.6	21654	422	42	13.0	21880	402
..	22076	398	43	12.6	22282	407
..	22474	416	44	13.5	22689	424
..	22890	429	45	13.2	22113	417
7.8	22319	411	46	12.5	22530	410
8.2	22730	422	47	(13.0	22940	420
7.5	24152	396	48	..	24360	400
9.3	24548	397	49	12.4	24760	380
8.8	24945	395	50	13.0	25140	410
8.9	25340	420	51	12.6	25550	418
..	25760	415	52	12.5	25968	424
..	26175	396	53	12.5	26392	388
8.4	26571	405	54	11.7	26780	400
8.2	26976	399	55	12.0	27180	410
8.2	27375	395	56	..	27590	393
8.4	27770	411	57	..	27983	407
8.7	28181	419	58	..	28390	428
8.2	28600	410	59	12.3	28818	405
8.1	29010	408	60	12.5	29223	409
..	29418	402	61	12.4	29632	401
..	29820	420	62	12.6	30033	417
9.0	30240	410	63	12.0	30450	430
8.5	30650	440	64	..	30880	420
8.8	31090	420	65	..	31300	425
9.2	31510	410	66	13.0	31725	433
9.6	31920	422	67	13.2	32158	417
9.7	32342	438	68	12.9	32575	435
9.0	32780	445	69	13.8	33010	423
9.2	33225	432	70	13.4	33433	427
8.4	33657	428	71	..	33860	442
8.6	34085	419	72	13.2	34302	446
9.2	34504	..	73	13.6	34748	..

Observations received during June, 1954: During June, 48 observers contributed 3222 observations, as follows.

Name	No. Var.	No. Ests.	Name	No. Var.	No. Ests.
Adams, Robert M.	59	155	Kastin, Harold	44	158
Anderson, Curtis E.	105	137	Kelley, Leo A.	25	27
Aronowitz, Charles	89	231	Kelly, Frank J.	12	15
Barber, Walter F., Jr.	2	5	de Kock, Reginald P.	133	536
Beidler, Herbert B.	32	101	Lonak, Eugene	3	7
Bicknell, R. H.	14	96	Maran, Stephen	44	48
Boutell, Hugh G.	5	12	McPherson, Charles	4	4
Buckstaff, Ralph N.	18	31	Miller, William A.	4	4
Chester, Arthur	8	10	Montague, Allen C.	47	74
Cragg, Thomas A.	172	180	Oravec, Edward G.	103	281
Darsenius, Gunnar O.	9	12	Parker, P. O.	18	18
Diedrich, DeLorne	6	6	Pearcy, Robert E.	5	5
Diedrich, George	17	37	Peltier, Leslie C.	21	91
Fernald, Cyrus F.	123	188	Perry, Wendell L.	14	19
Ficonetti, Rene	21	31	Renner, C. J.	156	169
Ford, Clinton B.	86	87	Rick, Louis	2	3
Gaustad, John	9	9	Rizzo, Patrick V.	17	27
Goodsell, J. G.	5	5	Rosebrugh, David W.	13	44
Hallock, Peter F.	1	5	Royer, Ronald	20	31
Hartmann, Ferdinand	123	125	Schultz, Gerald W.	1	3
Hein, George	14	40	Thomas, Morgan A.	1	1
Herring, Alika K.	7	7	Weitzenhoffer, Ken.	4	4
Johnsson, Robert G.	5	5	Wells, Karl A.	16	96
Juarez, Angel	13	13	Wyckoff, Jerome	18	29

Nova Search Programme: Reports were received from the following five observers during June. Listed for each observer is the month the observations were received, the areas observed (in italics), the number of nights the region was checked, and finally, the limiting magnitude.

Diedrich, DeLorne, June–*94*: 1, 3.
Diedrich, George, June–*Dome*: 3, 2; *56*: 1, 6; *56*: 4, 5; *78*: 3, 6.
Rick, Louis, June–*Dome*: 8, 2; *63*: 3, 4.
Rosebrugh, David W., June–*Dome*: 4, 3; *Dome*: 2, 2.
Wells, Karl A., June–*1–22*: 6, 4.

A.A.V.S.O. Headquarters
4 Brattle Street
Cambridge 38, Massachusetts
July 1954

MEETINGS OF THE SOCIETY

AT VICTORIA

January 13, 1954—The meeting was held in the auditorium of the Victoria College-Normal School Building with Mr. R. S. Evans, President, in the chair.

Mr. Bob Peters spoke on current phenomena mentioning the principal stars in the constellation of Orion, and also that the ending of the total eclipse of the moon on January 18 would be visible here.

The speaker of the evening Dr. Anne B. Underhill of the Dominion Astrophysical Observatory was introduced by Mr. R. S. Evans. The subject of Dr. Underhill's lecture was "The Development of the Reflecting Telescope".

The speaker traced the development of the reflecting telescope from Newton, who was the first to construct a working model using speculum metal for the reflecting mirror. All later developments were modifications of Newton's, notably the Gregorian, Cassegrain and Herschel reflectors. Dr. Underhill pointed out that from the first decade of the 17th century until 1900 the refracting telescope was the most important; the reflecting telescopes are a development of this century. The great advantage of the reflector is the ability to focus all colours together; the chief disadvantage, the small field of view. Slides were shown illustrating various types of reflecting telescopes and mountings, from earliest periods up to the most modern instruments of to-day. Other important steps in the development of the reflector were outlined: the use of Pyrex glass and fused quartz for mirrors; the substitution of aluminum for silvering; the Schmidt wide-field reflector.

The speaker was thanked for her most interesting lecture by Mr. R. S. Evans. The meeting was adjourned.

February 10, 1954—The meeting was held in the auditorium of the Victoria College-Normal School Building with Mr. R. S. Evans, President, in the chair.

The following were elected to membership in the society: George Lee; Mrs. C. W. Tubbs; D. C. Wyatt.

Mr. R. S. Evans gave a brief talk on the satellites of Jupiter, and, with blackboard illustrations, described how the amateur, with a small field glass or telescope, could observe the eclipses, occultations and transits of the four larger satellites.

Mr. Bob Peters spoke on current observable phenomena.

Mr. J. L. Climenhaga introduced the speaker of the evening, Dr. A. G. Hill of the Victoria College Physics Department, whose subject was "Applications of Radar".

Dr. Hill commenced with the development of radar during the last war and its application in the detection of range. A detailed description of transmitters and receivers was given with the aid of demonstration apparatus set up on the stage. The speaker elaborated on the functioning of the radar beam in computing distance

and time and speed. Reference was made to modern industrial uses of radar as well as to its use in ships and airplanes.

Mrs. E. C. Head proposed a vote of thanks to Dr. Hill. The meeting was adjourned

March 10, 1954—The meeting was held in the auditorium of the Victoria College-Normal School Building with Mr. R. S. Evans, President, in the chair.

Mr. Bob Peters, Director of Telescopes, gave his talk on current phenomena in the form of a questionnaire, requesting members to name the principal stars of certain constellations and to give their present positions in the sky.

Mr. Stokes gave a brief talk on libration of the moon and on observations of the Great Nebula in Andromeda.

Dr. Andrew McKellar, Honorary President, gave a lecture on "Probing the Atmospheres of the Giant Stars." First, the operation of the astronomical spectrograph was described, the structure of spectrum lines and their use in comparing data obtained of the chemical composition of the atmospheres of stars. Eclipsing binary stars and the effect of the light of one star on the atmosphere of the other during partial eclipse were examples which provided much information of value in the study of stellar atmospheres. Dr. McKellar discussed the complexity of the spectra obtained and the interpretation of them.

Mr. R. S. Evans thanked Dr. McKellar for his interesting and instructive lecture. The meeting adjourned.

April 7, 1954—The meeting was held in the auditorium of the Victoria College-Normal School Building with Mr. R. S. Evans, President, in the chair.

Dr. R. M. Petrie, Director of the Dominion Astrophysical Observatory, introduced Professor Hermann Bondi, formerly lecturer at Trinity College, Cambridge, England and now Professor of Applied Mathematics at King's College, University of London, England. Professor Bondi has been most active in the field of mathematical analysis and has contributed much to the problems of stellar structure.

Professor Bondi spoke on "Modern Trends in Cosmology," showing us how the nature of the universe ceased to be a philosophical subject and became a science 130 years ago when the German astronomer Olbers made certain assumptions about the nature of the universe and on the basis of these assumptions theorized a certain physical consequence which was not in agreement with the observed fact. This set of assumptions was therefore disproved and that is the point at which the science of the nature of the universe and progress in that science began.

Professor Bondi went on to show how the assumptions of Olbers could be modified in order to construct a theory of the nature of the universe that is in agreement with the observed fact. This theory assumed that the universe is young, that it is expanding and that matter is being continually created. It is now necessary to wait for further observation for the proof or disproof of the new set of assumptions.

Mr. Gordon Shaw moved a vote of thanks to Professor Bondi for his lucid, instructive and entertaining lecture.

Mr. Evans announced that the annual summer course would be held in August, with four lectures and a trip to the Observatory planned. Mr. Evans also expressed the hope that an active observers' group could be organized in September.

The meeting was adjourned.

F. R. Williams, *Recorder.*

AT MONTREAL

Meetings of the Montreal Centre held during the 1952–1953 Season.

October 23, 1952–G. Harper Hall: "Wings Across the Moon", Observations of Bird Migration. Annual Meeting and Election of Officers.

November 6, 1952–H. F. Hall: "An Introduction to Astronomy".

November 20, 1952–Dr. W. H. Carmichael: "An Historical Review of the Investigation of Cosmic Rays".

December 4, 1952–J. W. Duffie: "An Introduction to Astronomy", Part 2.

December 18, 1952–Visit to Planetarium–Montreal High School.

January 15, 1953–Dr. J. W. Rabinowitch: "The Art of Scientific Investigation".

February 5, 1953–C. S. Beals, Ph.D.: "Our Universe as We Know It To-day".

February 19, 1953–E. R. Paterson: "From Fetters to Freedom".

March 5, 1953–Mrs. J. Hartness Beardsley: "The Importance of the Occultation Programme".

March 19, 1953–B. Cockhill: "The Nature of Globular Clusters".

April 9, 1953–Symposium: "Personality Sketches of Three Great Makers of Astronomy".

April 23, 1953–W. H. Birtles: "Mathematics–The Language of Science".

May 14, 1953–Discussion–"Interplanetary Travel, Can it be Accomplished in the Near Future?"

Meetings of Montreal Centre held during 1953–1954 Season.

October 29, 1953–D. E. Douglas: "Dating the Past with Radiocarbon". Annual Meeting and Election of Officers.

November 12, 1953–W. H. Birtles: "Children of the Sun", first of series on fundamentals of astronomy.

November 26, 1953–E. R. Paterson:"The Recent Jolt in Astronomy", general results from the changing of the zero point of the Cepheid curve.

December 10, 1953–W. E. Leeson: "The Sun by Day–The Moon by Night", second of series on fundamentals.

January 14, 1954–Chas. M. Good: "Meteors and Comet Tales", third in series on fundamentals.

January 28, 1954–D. W. R. East, J. Borden: "Uses of Radar in Meteorological Research".

February 12, 1954–J. F. Heard, Ph.D.: "The Solar Eclipse of June 30, 1954".

February 26, 1954–H. F. Hall: "A Handful of Stars", fourth in series on fundamentals.

March 11, 1954–F. Morgan: "The Milky Way", fifth in series on fundamentals.

March 25, 1954–D. E. Douglas: "Modern Alchemy".

April 8, 1954–E. E. Bridgen: "Beyond the Milky Way", sixth and last in series on fundamentals.

April 22, 1954–A. Vibert Douglas, Ph.D.: "International Co-operation in Astronomy".

May 13, 1954–Report of Director of Observations. Performance of the Story of Frederick.

AT TORONTO

February 9, 1954—The meeting was held in the McLennan Physics Laboratory. The President, Dr. W. R. Hossack, was in the chair.

Mr. J. Ketchum gave a brief report on the Telescope Makers' exhibit at the annual Hobby Show. It promises to be more popular than ever this year.

Dr. Hossack introduced the speaker, Dr. Donald A. MacRae, Associate Professor of Astronomy at the University of Toronto. The title of Dr. MacRae's address was "Radio Astronomy and the Milky Way".

Dr. MacRae began his lecture with a brief description of what radio astronomy is and its history. In radio astronomy radiation with wave-lengths 1 cm. to 18 metres is collected by means of a radio telescope which consists of an antenna, a receiver and some sort of recording device. With such telescopes astronomers to-day are engaged in studying the Milky Way, the sun, interstellar matter and other celestial sources of radio radiation.

Clouds of interstellar gas consist mostly of hydrogen. Ionized hydrogen (H II) regions are found in the vicinity of hot O-type stars. Presumably beyond these regions unionized hydrogen (H I) exists, but it has not been detected. The temperature of the H II regions is about 15,000°K., and that of H I about 100°K.

It is possible to compare our galaxy with the Andromeda nebula. It has a condensed nucleus and a disk, it contains galactic clusters, globular clusters, interstellar gas and emission objects, all familiar members of our own galaxy. Like our own galaxy, it rotates. We see that it has spiral arms, which raises the question, does ours? Since the bright stars and H II regions are the tracers for the outer spiral arms in Andromeda, it is reasonable to suppose the same is true of our galaxy. H I could also be used as a tracer if detectable. H II has the advantage of being detectable in the Andromeda nebula where bright stars are not visible. Dark nebulae or dust clouds are used as tracers for the inner regions of Andromeda.

In 1944 van de Hulst predicted the emission of H I at 21 cm. This is a line of the hyperfine structure of the hydrogen atom caused by the change of spin of the electron. The frequency of this line can be measured very accurately, and with methods similar to those used with optical spectra, the Doppler displacement can be measured and the radial velocity of the object emitting the 21 cm. H I line may be obtained. In this way it is possible to obtain some idea of the motions of interstellar clouds in our galaxy and more information about galactic rotation. By measuring the intensity of the 21 cm. line an estimate of the density of H I can be found and leads to a value of 9/10 hydrogen atom per cubic cm., a result that agrees well with other estimates. From the distribution of high density regions, it is possible to show that our galaxy has evidence of spiral structure.

Many other interesting results are rapidly coming to light, and radio astronomy promises to solve many of the problems connected with our Milky Way.

BARBARA CREEPER, *Recorder.*

X

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Address of Editors: David Dunlap Observatory, Richmond Hill, Ont.

Business correspondence and remittances should be addressed to J. H. Horning, Treasurer of the Society, 13 Ross Street, Toronto 2B.
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